Shuttleworth, J. G.
The hydraulic railway.

3

Geo. H. Williams
Friday. 8 July 1842.

THE

HYDRAULIC RAILWAY;

BEING A CAREFULLY DIGESTED,

BUT

PLAIN STATEMENT

OF

THE ADVANTAGES TO BE DERIVED, AND IMPEDIMENTS REMOVED,

IN ESTABLISHING

HYDRAULIC PROPULSION,

ON RAILWAYS.

BY J. G. SHUTTLEWORTH,

(THE PATENTEE.)

London:
J. WEALE, HIGH HOLBORN,
MANCHESTER: J. & J. THOMSON, MARKET STREET; SIMMS AND
DINHAM, EXCHANGE STREET; AND ALL BOOKSELLERS.
1842.

MANCHESTER:
SIMPSON AND GILLETT, PRINTERS, 78, MARKET STREET.
1842.

ADVERTISEMENT.

It is hoped that the attempt, which will be manifest in this pamphlet, to render the subject-matter of it, with its several ramifications, interesting to the general reader, will be viewed in the right light by the engineer, and man of science. It is desirable that every one, who has the opportunity, and however humble his pretensions may be, should study to make the subject of any writing, which may furnish occupation for the mind, and exercise for the mental faculties, as widely acceptable as possible; and this, with much pleasure, it may be observed, has become a leading feature in many of the more recent scientific publications. It may be also mentioned, that the invention, which is advocated in the following sheets, is of a nature which seems to suggest the propriety of its being introduced, if possible, to the public, through the medium of such a style of writing, as may render it generally simple and easy in its perusal to such members of the community at large, as may take up the pamphlet; but still, so as not to detract from the interest, which philosophic and learned minds, and practical mechanicians, may feel in the question at issue.

The writer of this pamphlet is anxious also to avail himself of this, as being the earliest opportunity, to apologize for the length of it. But, when it is remembered, that a treatise on railways, or on the locomotive, or stationary engine, is not looked upon as having, within 500 or 600 pages, reached an unreasonable extent, it is hoped, the length of the present pamphlet will not be objected to, as it comprises the clear explanation—if the writer is competent of this—of a re-adjustment of no small portion of a most extensive system.

PREFACE.

There are two ways of writing a book; one is by putting a colouring, as it is termed, on the subject of it, and veiling or distracting attention from its least promising features; the other is by meeting the question fairly and at once, in its most unfavourable aspect; with the assurance that if this is successfully encountered, the question will gain strength from the investigation, in the exact ratio in which seeming obstacles in the way of its advantages, have been removed. I have preferred the latter mode. I do not wish to give others the trouble of pulling this pamphlet to pieces. This may often be done in the spirit of perfect honesty and to demonstrate the truth; and, when so undertaken, the dissection of a publication—for it is no longer a mere pulling to pieces—is not the less severe because the operation is performed with urbanity; indeed, when strict and not unfriendly truth is the dissecting instrument, and the subject-matter is *diseased*, the cut is frequently deepest.

I have therefore met the question, which I have set at issue, in its several branches, in its least favourable development, and have reviewed the subject under the light, which science and its acknowledged principles throw upon it; testing that review by accepted data. I may have made mistakes, notwithstanding the long and deep study and attention, which I have bestowed upon this question; particularly as the subject is new, and the arrangement therefore of its several ramifications, and the proportioning throughout of its machinery, have been no trifling undertaking; but I do trust that nothing like an intentional error will be considered, by any candid reader, as apparent in the following pages.

At the same time let me not deceive any one. For about a period of twenty years, a soap-maker by position, and from peculiar circumstances, strictly a secret student of some branches of science, [illegible] my pretensions must be as humble as my opportunities of acquiring the best, most available, and useful information were for a long period in [illegible] and it will not, I flatter myself, be expected by any [illegible] that the terms of art will flow as freely [illegible] of science—especially in those [illegible]

power to devote any particular attention, will be as freely open to me, or its language as familiar to my pen, as if art and science had been the whole, or at least the main, occupation of my life. From any awkwardness of manner or arrangement, I appeal to the subject-matter, and from any imperfection in style of writing or diction, I appeal to the question at issue. If that question is worthy of attention, and is found to hold out good promise of beneficial results, either to the community at large, to the scientific world, or to Railway shareholders, the phraseology in which it is dressed, and the manner in which it is treated, will, I feel assured, by the general body of my readers, be esteemed far less worthy of their attention than the grounds on which it is presented to their notice, and the probable soundness of the position it assumes.

I have often found awakened attention in the subject of scientific works strangely interrupted, and the ideas or conclusions to which they were drawing the mind of the reader, awkwardly checked, by lengthened references to plates and drawings, with all their minutest detail, in the midst of the most interesting portions of such works. In the present instance, to remedy this, as far as the case may admit of, I have separated much of this sort of description from the body of this pamphlet, and have preferred attaching a sort of tabular reference or index to the drawing, at the end of the book. For the same reason, I have there been rather more explanatory on the general nature, and some of the various parts of the invention, than is usual in a "Description of the Drawing;" so much so, I hope, as to have rendered it capable of furnishing, to many of my readers, a preliminary general idea of the principle here called into operation, and of its probable effects. Still, I have been very desirous throughout the pamphlet, to avoid an extreme minuteness of description wherever all was manifest, both as regards the machinery and its action—instances of which, are sometimes met with, that would be almost amusing, if time were no object whatever, and if attention could be given, long after the understanding was satisfied. The references however are more numerous than I anticipated on a subject so simple; but my first surprise at this was removed, when I considered what number of references would be requisite to describe the whole machinery of a locomotive, and what greater number must be added, if, not a locomotive only, but also a large portion of the whole working system of railway were, according to its present arrangement, and for the first time, to be brought before the public.

Still, I may have occasionally treated some portions of the general subject of this treatise, in a manner that may appear lengthy to several of my readers. My object has been to render the m[illegible] here it was at all material, clear. At any expense of labour [illegible] ndividually,

THE

HYDRAULIC RAILWAY.

CHAP. I.

THE first and great objects of science—particularly of mechanical science—are, through physical acquisitions, to advance the general happiness of mankind. To add to the conveniences and economize the means of the human race, is generally tantamount to promoting material comfort, domestic happiness, and social enjoyment; it is often, the same thing as to remove the pressure of contracted circumstances, to give buoyancy to the mind and to restore vigour to the human frame. Objects such as these, constitute the best claims of science on public support and general esteem.

The grand achievement of late years, in mechanical science, has been the establishment of railways. These, with their wonderful machinery and general economy, engross no small share of the attention of the whole of the public, from its lowest members up to "Home Secretaries," both in Europe and America. Another quarter of the globe is likely soon to feel their influence; and railways must shortly become most interesting subjects of enquiry, as respects the prospects they may offer for the advantageous investment of capital—embracing necessarily the modes and opportunities for their construction and practical arrangement—in India, if not also in other parts of Asia.

It would be trite then to say that railways are concerns of national importance. No one disputes it; their results v negative such an assertion. Their share market clai place in the public journals, by the side of the stoc

places which were remote, are, through their agency, and for all practical purposes, no longer so; and time which was lost, is now saved. A man may drop asleep in his travelling "easy chair," in a railway coach in the evening at Darlington or Lancaster, and wake, with the early dawn, in London. Correspondence, which was tardy and lagging, now flies from one end of the Empire to the other, at a speed, totally eclipsing that which government couriers, but a few years back, boasted when mounted on the fleetest horses. The community, in many of the comforts and necessaries of life, have equally experienced the beneficial effects of the railway system, as the state of the meat, the poultry, the vegetable, and other markets in the larger towns sufficiently testify; and the great manufacturing marts are benefited to an extent which, though closely observed by comparatively few, is too great for any but a political economist duly to calculate. The agriculturist also derives great advantage from the proximity of a railway, in the swift conveyance it offers him, for the produce of his farm to market.

Railways therefore in their effects as at present developed, may, without the slightest exaggeration, be said to be wonderful; and in the development of their future effects, they are already working a change in the whole framework of society, peaceable and without strife, which in a comparatively short space of time, is likely to exhibit to the world, consequences of a magnitude greater than those which have arisen from revolutionary convulsions, the march of victorious armies and the longest wars; and in most respects of a character, very opposite to that of the results, which such epochs in history have afforded. Napoleon himself pointed to a road (the Simplon) as the most lasting and trustworthy monument of his glory: little did he imagine, that even his great work must sink into comparative insignificance before the labours of a few years' continuance, of English engineers—without considering the great railway works on the continent and in America—when supported in their stupendous undertakings by the countenance of the British public, and aided by the powerful lever of British capital.

When these effects are borne in mind, and when it is recollected that, where we travelled at the rate of ten miles an hour—

which, fifteen years since, was considered a maximum exertion—we now *glide* over the country at a speed of twenty miles, or more; and when it is remembered that places, which, as regards the public at large, were considered so remote as to be seldom or never visited, unless the emergency of the occasion rendered such an effort indispensable, are now "run down" to, in a few hours, as being merely a morning's trip; and when also the tradesman recollects that he can now have his goods down in the country in a few hours, which on the old system, required several days in transit; it will not appear extraordinary that the wonder of the public at this great change, should for a time have so far absorbed its clear powers of reflection, as to render it nearly indifferent to the question as to whether its first expectations of the benefits to accrue from this extraordinary feature of our times, had been altogether realized; and whether improvements, every way advantageous, could not yet be introduced into the system of locomotion. But it appears the period is arrived when enquiry is beginning to resume its wonted energy; and questions are now exchanged every day among the community at large and in the public prints, indicative of doubt whether the locomotive system has at once started into existence in a state of absolute perfection, and, unlike every other invention which the world ever witnessed, incapable, at least in its leading features, of all improvement. It was anticipated, not that time only would be saved, but also that the expense of transmission either of goods or individuals, would be considerably reduced by steam-locomotion, in which iron supplies the place of horses, and coal, the place of hay and corn; but the enormous annual cost of "maintenance of the way," including the whole locomotive department, has, for the present, set that question at rest. It was expected that this mode of travelling would be exempt from frightful casualties; and "railway accidents" now occupy a conspicuous place in the columns of every weekly journal. It was greatly hoped—almost promised—that this system would extend its arms right and left, till it reached into every town and populous locality; but the public were at length informed, better experience had demonstrated, that these "Branches," if established at all, must be undertaken by each separate town, and that the good burgesses, to accomplish such desirable object-

must be prepared almost literally to cover the foundation of their proposed railways with gold. And punctuality, as regards time of arrival, seemed with the apparently powerful moving engines, a circumstance of easy and certain attainment; while it is now proved that wet, frost, fogs, wind, and the numerous minor accidents, to which the machinery of locomotives is so peculiarly subject, render all certainty as regards the time of arrival, both with respect to passengers and mails, frequently much more questionable by railway-locomotion than on the former system of travelling, by coaches on the turnpikes.

Such appearing to be the actual position of the railway system at the present time, it is imagined that this pamphlet is offered to the public and railway proprietors not inopportunely; and it is therefore hoped, that its statements, calculations, and propositions will be received with the frankness and candour in which they are offered, and will be considered with the care and attention due to proposals, which, if founded on correct data, embrace in their principles, much public benefit, and, as respects railway shareholders in particular, great individual advantage and profit.

The author begs to state, that he has submitted his invention to the first scientific and engineering characters, with whom he has the pleasure of being acquainted, and, though solicited to point out any objection to the working of his system, if any such were apparent, nothing of such a nature has presented itself to the minds of any of these gentlemen; indeed, the answer has frequently been, that the system appeared so reasonable in drawing and description, that it was now advanced into that position, which called for its merits being brought to the test and decision of a full practical trial. Though something, partly of this nature has been already alluded to in the preface, it seems not improper to repeat this here; for hydraulics is a science which has been less popular and less studied than several others; hence, its capabilities may not at first, and until they have been a little enlarged upon, be so fully appreciated by some of my readers, as they deserve. But the powerful agencies which this leading branch of hydronymics commands, offer it, particularly in its wider ranges and more active energies, as a subject well worthy of attention. Its greatest capabilities have been [illegible] ver-

looked, or but passingly alluded to, especially in what is termed "popular information," and their place has been supplied by amusing accounts of *jets deau*, adjutates, fountains, and all the trifling water-work gambles which this liquid was made to play for the pleasure of Louis the 14th at Versailles; and in mere illustration of which, some of the experiments still quoted in works on hydrostatics, appear to have been originally undertaken; while many facts, demonstrations and conclusions which much research and study can furnish, afford striking indications of this science being not remotely destined to step in with its great resources, as a first mover of machinery much more frequently than it is now. It is a science less perfected, and with its forces and proportions less developed and demonstrated —or when demonstrated they are so through the medium of formulæ, which, though based on experiments, are generally arbitrary—than many others which cannot claim its gigantic powers and capabilities to work well for mankind;* but it is to be hoped that most of the mist which may still hang around some of its nobler proportions, will be shortly cleared away; for attention has been drawn to this subject from a quarter well deserving of respect and notice.†

In the meantime, fully sufficient has been done in this science to elucidate, for all practical purposes, the subject I am now to treat, and upon which I shall be particular to make myself clear in the following sheets; after the perusal of which, it will remain for my readers to decide whether this application of hydrostatic propulsion does, or does not hold out strong and reasonable promise of its capabilities to move forward our railway system another step in its extraordinary career—probably scarcely less efficient, as regards simplicity and power, and generally as little anticipated by the public at large, as was its former advance by locomotive engines, prior to the opening of the Manchester and Liverpool Railway. I will now, therefore, avoiding [illegible]

* See Note A.

† Rev. William Whewell, [illegible] and in the chapter on "The [illegible] remarks, "Even up to the [illegible] reduce problems concerning [illegible] calculation, without [illegible]

hundred thousands; and would Acre, the *impregnable* Acre, have been so easily captured, and our other exploits recently in the Levant, or at the present time taking place on the coast of China, prove, with so much facility, the wonderful superiority of Great Britain, without the aid of this power? And, yet, when the steam engine is brought to act upon water, I am not, I think, guilty of exaggeration, when I say, it goes tremblingly to work: witness its slow heaves and *pauses* as its machinery reciprocates its action; observe its air vessels to moderate the shock of the water when its progress is interrupted, and, if the pump be large, attend to the clash of its valves. A power like that of water is not to be reciprocated without due caution; throw a little too much momentum into a substance so ponderous, yet, when once in motion, so responsive to the lift of the engine; so incompressible yet subtile, and, but for the air-vessel, it would seriously strain, if not fracture, the ponderous, but well-proportioned machinery, even of the steam engine itself!

Still, under able engineers, all these apparent elements of discord are so well equalized into harmony, that the steam engine forcing or lifting pump, is everywhere to be found contributing greatly, in one of its most ordinary positions, to the comfort of the population of London, and many other of our towns; where it becomes the medium for supplying their inhabitants with wholesome water. I mention this, more clearly, to bring before the minds of my general readers, the power of my propulsive medium; not to convey to any one the idea that I shall apply that medium with a reciprocating action up my propulsive piping; far otherwise; for the power of the rush of the water, or, in other words, its momentum, will be entirely unchecked by any reciprocation, and all in the direction in which I require it to propel the piston, and, through that, the train.

It is true, I shall occasionally apply the steam engine forcing pump as a *first medium* for conveying propulsive power to the water. That is, where natural heads of water of sufficient elevation, or smaller falls to work hydraulic machinery, are not, by the aid of piping, within convenient reach. The question of the distance from which water might be conveyed, to furnish supplies to reservoirs, under adequate pressure, to feed the propulsive pipes, is less material, than the question of amount of

expense, and the consequent length of connecting pipe, which, in an economical point of view, would be advisable—*for water might be brought, from elevated ground at a considerable distance, without material retardation in the pipes, or consequent loss in propulsive power, if pipes of sufficient bore were laid to convey it, so that it should travel along them, at a speed comparatively slow.* Steam engine lifting, or rather force pumps, therefore will be, as I have just intimated, occasionally indispensable; and on such occasions I rely on the great results which such engines afford in Cornwall, for their agency proving far more economical on railways, than a cursory glance at the question might induce us to imagine. The opinion I now offer, I trust I shall be able fully to establish to general satisfaction, when I come, in the following pages, to the details on this matter. Cornish steam engines consume 2½ lbs. of coal per horse power per hour, while the Manchester factory engines, under the same conditions, consume 10 to 12 lbs. or even more; and other stationary engines, of the ordinary construction, are esteemed very successful mechanism, whenever they can bring down their average consumption of coal to 8 lbs. per horse power per hour.

The duty obtained from the Cornish engines is now undoubtedly very great; but what would it become, should the "pliable solid," as water has been aptly termed, which they have to lift, be eventually as completely [illegible] by engineering skill and perseverance, into perfect and [illegible] tractability, as the prodigious force and [illegible] of steam is at the present moment in the steam engine itself.

This is not to be considered very hypothetical. What is now more common than the high-pressure engine? [illegible] locomotive be worked on any other principle? [illegible] Cornish engines perform their [illegible] it? And yet, Mr. Watt himself [illegible] this principle by experiment [illegible] though he [illegible] mistaken conclusion [illegible] the experiment [illegible] plished [illegible] it would be [illegible]

those engines at present contend, with marked success, shall not yet become more immediately ductile and responsive under the reciprocating action of their powerful great beams. The power of the natural flow of water in a continued stream can be estimated, and the result so obtained is very great; but the ebb—or pause—and flow of the water on the Cornish principle, must detract much from the efficacy of those great and still successful engines; and it is to be hoped, the period is not far distant, when the science of hydraulics will be so far advanced as to enable them to bring up the water in one continued stream, and without sacrificing, as at present, the momentum which, with the first energy of their high pressure steam, they create in this strong incompressible liquid, and suffer again to die, after every lifting stroke they make. Though the stream so established, would be in a vertical, instead of horizontal direction, yet the comparison here instituted, as respects the amount of its effects, and the difference between a free natural flow of water and an intermitting stream, will, in the two cases, hold good, when the circumstances are borne in mind, to a sufficient extent to justify its being adduced in illustration of the idea now advanced.

A material characteristic of liquids, is their disposition to acquire a true horizontal level. The first use they make of the facility of motion by which they are distinguished, is to exert it in regaining this level, whenever it has, from any cause, been disturbed. It matters not whether a torrent has precipitated itself down the face of a mountain, or a river poured itself into one side of a lake, or whether one end of a tube full of water, has been bent upwards, or whatever else may have occasioned the disturbance of the water-level; that level, if the liquid be left to itself, will be regained, and the more speedily regained, in exact proportion to the extent or height of the disturbing cause. Distance cannot neutralize this law of hydrostatics. Whether the surface or horizontal column, whose level has, at one side been disturbed, be ten yards, ten miles, or any other measure in length, the liquid immediately begins to exert the power of motion, inherent in it, under such circumstances, to regain its true horizontal level; and it never will be in an absolute state of rest, until that is accomplished.

I have already alluded to the fact, that the water-[illegible] of

some of our large towns supply water ...

their mains and branch pipes ...

communication. The means of power ...

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Some large towns ...

[illegible]

[illegible] When [illegible]

[illegible] work [illegible]

[illegible]

It would be very desirable, if it could be demonstrated ... principles, so easy of application, govern the fall of water ... closed vertical pipes. Authorities might be brought forward ... support this doctrine: and could it be established, it would ... inherent in the mode of propulsion I advocate, a still gr... amount of power than I at present feel justified in claiming ... but it too frequently happens, that these authorities, when ... claim so much, in some other portion of their own works ... entirely show that such estimates are in error. Thus Desag... translating Marriotte, at page 170, alluding to the accel... ... of descent in falling bodies, says: "The water ... through the vertical pipe would increase *according to* ... *numbers*, if there was only the pipe." But the reason he ... for this assumption is quite unsatisfactory: and the ... the work itself, a little lower down, negatives the idea. ... also might be quoted to the same effect. This may be ... in a portion, in italics, of the passage I have extracted ... of the ... of this pamphlet, as being, in his rather quaint ... beautifully illustrative of some peculiarities in the verti... water, as well as of other bodies.* One of the ... Tredgold's Tracts, ... also hazards the same ... stating that "The fluid stratum, continuing to descend ... in a cylindrical tube, tends to accelerate its motion ... to the laws of gravitation" — page 139, second edition. I am afraid, is one of those instances in which he ... self to the observation which Tredgold makes in his ... the inferiority of his judgment, and which remark ... able editor, I have already transcribed in Note A.

In that note also, there is abundant confirmation ... merited eulogy it bestows on Dr. Young's work, ... security of the basis on which I place myself when I ... formula, which Tredgold derives from Dr. Young's S... Eytelwein's Hydraulics—in rejection of more favou... ciples, which the preceding quotations would seem to ... —as the foundation of my caculations in the follow... This rule or formula does not show that water in verti... falls exactly according to the laws of gravitation, o... whole velocity due to them; and for this sufficient re...

* See Note C.

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[illegible] own with the liquid: [illegible] gradually again [illegible] of the descending mass. In vertical piping, therefore, the retardation from this cause is [illegible]: [illegible] in that last previously [illegible]. The other actual obstruction also—which obtains only in vertical lines—is of much greater moment: and though its effect [illegible] that of the retardation, which I have just explained, is included in the formula which I am about to introduce to the reader, I will here endeavour shortly to describe its character.

Water falling freely through a vertical pipe will, particularly if the pipe be of any length, have a *tendency* to create a vacuum in some part of it, owing to the water towards the top of the pipe being, according to the laws of gravity, disposed to fall at a slower rate than that towards the bottom of it. This is well alluded to in [illegible], to which I referred the reader two or three pages back. Now this tendency to a vacuum is beautifully counteracted by the pressure of the air, which at the top of the column acting on the head of the water, forces it down the pipe with a velocity greater than what is there due to it from gravity, to fill up what would otherwise be vacuity. At the bottom of the column, the same pressure of the air becomes of opposite effect; and there meeting the force of the discharging water, partially obstructs its free egress, and allows the water towards the top of the pipe—with the aid of its own air-pressure—thus to maintain with the rest of the descending column, one well connected stream. Thus the pressure of the air divides its effect in preventing a vacuum in the pipe, equally between the top and bottom of the descending column of water; thus too, from its partially obstructive pressure on the bottom of the column, it detracts something from the velocity due, by the laws of gravitation to the descent of a vertical column of water through piping.

Ample deduction from the velocity of water in piping, for the retardation due to the above causes, as well as that due to the liquid in its passage up horizontal pipes, is made in the formula or rule in Tredgold's 'Tracts on Hydraulics, which I have promised to bring under the n[illegible] reader.*

For reasons, which will be sufficiently obvious, this formula or rule is much influenced in the amount of effect which it indicates, by the diameter of the pipe; and after a good deal of reflection, I have arrived at the conclusion, that the most convenient diameter for my driving or propulsion pipe, on a line of any considerable traffic, will be that of one foot. This will, in the first place, keep the pipe within very moderate dimensions; in the next, it will be of adequate capacity to conduct and render applicable, an horizontal column of water fully sufficient for working, with powerful effect, any railway now established; and in the last place, in a pipe of a foot diameter, I shall have to make less provision against the retarding influence of friction, than in one of smaller bore, for instance, one of six inches; because the friction, according to the commonly accepted rule, is as the diameter, whereas the supply is as the square.

It appears reasonable, also, to regulate the load of the working pressure on the propulsion column of water, as near as possible to those pressures, which are to be found in practical application among the great lifting or pumping engines. Not having at hand the exact length of the lifts of water in the great mines in Cornwall—which, however, must be considerable, as some of the mines are 500 yards, or more, in depth—I find by the printed description of an engine, constructed on the Cornish principle, by the eminent engineer, William Fairbairn, Esq., to drain a mine 720 feet deep, at Verviers, in Belgium, that two of the lifts, or rather lengths of pipe, are 180 feet each, the water, in both cases, being forced up by a plunger or ram. The pressures also to which some of the water works' companies subject their pipes, are occasionally very high. Even in this town (Manchester) in the midst of a comparatively flat district, the water works company's pipes are worked under a pressure of 140 feet ($4\frac{1}{4}$ atmospheres), and when of from 12 to 18 inches bore, and $\frac{7}{8}$ of an inch in thickness, are warranted to stand a pressure of 300 feet, to which they are proved; and I am assured, from sufficient authority, they would bear a great deal more. It will therefore be quite within reasonable limits to place the propulsion pipes for this system, under six free atmospheres at the commence of every section of piping, and under five at the end of it. occasionally require half an atmosphere extra, though

propulsion pipes; but on this subject, and also as regards the reason for working, first at six, and then at five atmospheres, as well as respects the dimensions of each "section" of the piping, just referred to, more will be said further on. For the present therefore, assuming that at the power-stations, the available force will be limited to that of six atmospheres—which is all the pressure I should wish to avail myself of, when I use these stations to furnish propulsive action to the driving pipes immediately contiguous—I find, by the formula I have given in the last note, that my initial velocity, at the foot of the vertical column, or its equivalent, will, under six atmospheres, represent a speed of full 67 $\frac{5}{6}$ miles an hour. The above initial velocity of course must be checked, or what could stand against it? and nothing can be more easy than to adjust the communication valve, placed between the vertical and horizontal pipe, so to open (partially) *at first*, as to give that amount of supply of water, which will furnish the decreased velocity, or nearly that, due to the further end of the pipe, when the retardation has been taken into calculation. The communication valve to effect the above purpose, is first acted upon by the pulley, as shown in the drawing, which, on being lifted by the inclined plane attached to the travelling truck, raises the valve about one-third: after this, the remainder of the opening is effected gradually by a little machinery, I also show in the drawing; it is done in such manner, as to preserve, in the propulsion column of water, through its whole course up the pipe, one equable velocity; and which clearly must be the same as the final velocity; thus, as the velocity first allowed to the water, in its progress up the pipe, tends to abate, this again tends to increase it, so as to preserve in it one unvarying speed throughout the whole of the pipe, now under consideration. This action of the communication valve illustrates one of the most beautiful laws in hydrostatics, and which is usually exemplified by the hydraulic press or by the hydrostatic bellows. These instruments show, that by contracting the upright pipe (in the case of the bellows, for instance), and thus reducing the supply of water, you reduce the speed or the quickness with which the instrument acts—for the speed is under complete control—but by doing so, *you nowise do, or can reduce the available pressure, and lifting power of the water*: that, under all circumstances,

remains, in the [illegible]
is not altered, [illegible]
of the base, multiplied [illegible]
and not by the [illegible]
hydrostatics, will [illegible]
system of propulsion [illegible]
moving piston, [illegible]
be considered [illegible]

To return [illegible]

[illegible]

(1) At the foot of the vertical column, a free power, driving weight, or impulse, for the purposes of propulsion, of	86 cwt. 2 qr. 14 lb.
(2) An initial velocity, in the same position, (if there uncontrolled) of........................	$67\frac{5}{6}$* miles per hour.
(3) A velocity in the horizontal pipe, at a distance of 50 yards from the vertical column, of	34 „ „
(4) A velocity at a distance of 70 yards, and which I have termed "final," of................	$29\frac{3}{4}$ „ „
(5) And if each length of horizontal propulsion pipe were to be considered as measuring 100 yards, instead of 70, the water would, at that distance from the vertical column, command a velocity of..	$25\frac{3}{5}$ „ „

All the conditions being the same as the preceding, except taking the propulsive pressure as *five* atmospheres, then

No. 1 would be	72 cwt. 0 qr. 21 lb.
„ 2 „ „	$61\frac{9}{10}$ miles per hour.
„ 3 „ „	$30\frac{6}{7}$ „ „
„ 4 „ „	$27\frac{1}{6}$ „ „
„ 5 „ „	$23\frac{2}{5}$ „ „

If under *four* atmospheres:

No. 1 would be	57 cwt. 3 qr. 0 lb.
„ 2 „ „	$55\frac{2}{5}$ miles per hour.
„ 3 „ „	$27\frac{3}{5}$ „ „
„ 4 „ „	$24\frac{1}{4}$ „ „
„ 5 „ „	$20\frac{9}{10}$ „ „

If under *three* atmospheres:

[illegible] would be	43 cwt. 1 qr. 7 lb.
„	48 miles per hour.
....	$23\frac{6}{7}$ „ „
....	21 „ „
....	$18\frac{1}{7}$ „ „

[illegible] opportunity, I can, if it should appear to be desir- [illegible] fractions introduced in different parts of this [illegible] it appears to me hardly consistent to [illegible] large scale, in hundredths. Would it seem [illegible] undertaken with a view to decide upon [illegible] and Birmingham Railway, to say, that [illegible] was, for instance, $21\frac{79}{100}$ (substan- [illegible] would be brought up to $22\frac{48}{100}$ (sub- [illegible]

to ou act beat by th instru case of of wate instrum by doing *and liftin*

CHAPTER III.

Having already mentioned, that it appears to be a reasonable course, and clear of either extreme, to propose working under propulsive powers of six and five atmospheres (which, in the language of the steam engine, are respectively equal to 90 lbs. and 75 lbs. pressure, or nearly so, on the square inch) I shall found the several calculations and estimates I may, in the course of the following pages have to offer, on these bases; and which, consequently, to be correct, must be in accordance, as far as it goes, with the preceding brief synoptical view of hydraulic power and velocity.

From all that has preceded, it appears, *therefore, that this* mode of hydraulic propulsion claims a velocity, as due to it at a distance of 70 yards from each power station, of $27\frac{1}{2}$ miles per hour. I shall *claim* no more for it; though there are strong grounds for presuming that the formula from which I derive this velocity, is inadequate duly to measure the effect and power of liquids, when rushing up pipes of large bore; particularly if then under the impulse of a powerful momentum. In one passage, I have quoted from Tredgold's Tracts in Note [illegible], illustrative of the principles on which his formula is founded, it is stated that the friction will be "inversely as the [illegible] or as the *square* of the diameter;" but a gentleman resident in this town (Manchester) whose scientific attainments in hydrostatics are beyond dispute, and whose opportunities of testing his acquirements in the science practically, are as decidedly favourable as his opinion on such subjects is universally respected, has mentioned to me that the results of his own experiments and those of an able scientific friend, have caused him to arrive at the conclusion, that in pipes of large bore, the friction will not be found to be reduced inversely as the square of the diameter, but more nearly as the cube of the diameter. The reason is, that the great bulk of the experiments which form the

[illegible]

of all the data, in works on hydronymics, have been undertaken with apparatus very inadequate to indicate the whole results of hydrostatic phenomena, when that science is called into a state of its widest and most powerful usefulness. The expense was too great to allow of apparatus being furnished, expressly to illustrate the power of this science in its greater operations. Hence, as opportunities were not afforded for determining this by direct experiment, analogy has been called in to furnish what was supposed to be a probable result; just as from analogy an argument might have been founded, before the opening of the Liverpool and Manchester Railway, on the probable power and velocity of the locomotives, from a lecturer's diminutive model of one of those engines. Or, when anything more practical than these diminutive apparatus was brought to bear on the question at issue, so little was known of the actual state of the machinery; of the accuracy, or otherwise, with which the piping was laid down; of its being clear of, or partially obstructed by air in it; the flexures in it, so much detracted from its free efficacy; and so inadequately was the great and powerful momentum of the water, by trying the higher velocities, brought into operation; that no data so obtained, were, or could be anywise likely to exhibit the full amount of the result sought for.

Having stated thus much to set myself right with the public at large, and also to render it pretty manifest that I do not claim *too much*, I have now only to repeat that I am prepared to found my statements and deductions, confirmatory of the power of hydraulic propulsion, on Tredgold's formula: it is the best, that, under all the circumstances, I can produce; or rather, I should say, it is the one most generally accepted, and least open to be demurred at, or questioned by any parties, on the score of indicating too favourable a result. I claim, therefore, no more than 27 miles an hour—though the actual speed is more likely to prove 30 or [illegible]—but this is on assumption, that I take my driving velocity [illegible] that due to liquid at a distance of 70 yards from the ver[illegible] and control the great previous velocity down to [illegible] The velocity due to the water at fifty yards from [illegible] might, probably be very safely taken as the [illegible] each length of propulsion pipe would then, [illegible] be curtailed; but it is far better to

have a little too much propulsive momentum, in an invention of this description, till proved in practice, than to run the risk of being anywise short of free power, and thus, from unevenness in the effect, to expose the trains, however remotely, to shocks or jerks, in their progress along the line.

I have now to refer my readers to the drawing and the reference to the figures, which will be found at the end of the pamphlet. The alternation of the sections of propulsion and skeleton piping there exhibited, particularly in Fig. 8—where, however, no proportions could be observed—will suggest, as a question; how the trains are to be carried over the skeleton lengths? I answer: they will be carried over the skeleton piping, with very trifling loss of speed (the exact proportion of which I shall soon have to consider,) by the very great momentum thrown into them, through the medium of the travelling piston, in their passage over the propulsion sections. What is the amount of this momentum? At the foot of the vertical column there is a weight, or load of water of 86 cwt. 2 qr. 14 lb. pressing to escape at a speed of $67\frac{5}{6}$ miles per hour. It may otherwise be termed a pent-up flood, seeking means of escape under this enormous pressure, and ready to bear before it, whatever is brought against it with a less opposing power. Now, to repeat a former statement, and save my readers the trouble of referring back, the drawing shows the machinery, attached to the communication valve. The inclined plane on the driving truck, through the agency of the pulley, &c., opens that valve at first, say, *one third*, so as to allow only such a supply of water through the opening, as shall at first furnish a speed of, *not quite*, 27 miles an hour. Then, as the train progresses, the aperture in the pipe under the valve, opens wider and wider, under the gravitating power of the load, so as fully to counteract the increasing retardation in the horizontal pipe, and to preserve in the water a velocity equal to that under which it first started; *or rather*, it will be a little increased. Now this is all perfectly easy of accomplishment. On inspecting the drawing of that part of the machinery, which is to effect this purpose, it will be found that the whole is as capable of being adjusted to the speed and circumstances under which it has to work, as a clock is by its pendulum, as a stationary steam engine, by its *governor* and throttle

inclosed, ponderous, current of water, under great pressure, and of considerable volume, shooting itself forward, with extreme velocity. It should be remembered also, that the larger and heavier the train, the more powerful its momentum becomes. This was several times well illustrated in Dr. Lardner's railway experiments, to which I have already alluded, where the heavier trains under, otherwise like conditions, exhibited a much greater impulsive power in them, than those which were lighter. Hence in hydraulic propulsion, heavy trains will be a convenience rather than an incumbrance, to a system, which, as respect propulsive power, will be absolutely master of any weight which can be compared with any thing, that ever ran before on iron rails.

CHAPTER V.

The exact ratio of the decrease of speed over a length of skeleton pipe, must now be inquired into; and, for determining this question, I am prepared to take such data as are already in being; but as these data are obtained from observed results on the locomotive system, it will, I trust, from all I have just urged, appear probable to many of my readers, that the inferences so obtained—though satisfactory as far as they go—will be insufficient in the present instance.

It appears that Dr. Lardner, while experimenting on the Liverpool and Manchester Railway, to determine the resistance to the trains in motion, undertook several experiments on the Sutton incline. In the course of one of these, mentioned in his second lecture, two coaches, weighted to the gross load of 11.33 tons, were brought to the top of that incline, and then suffered to descend by gravity. Now the Sutton incline is one in 89, and, according to M. De Pambour, 2,446 yards in length; and, at the foot of it, there is what may, for all practical purposes, be termed, a level, as it presents an incline only of one in 2,762, and which has a length of 4,241 yards. These coaches, in descending the incline by their own gravity, acquired a speed, the lecturer observed, of 28 miles and a fraction; and they ran, in all, a distance of 4,577 yards. Deducting from this, the length of the incline, it appears they were carried over 2,131 yards of level, by their momentum alone; their speed, at the commencement of this level, being, say 28 miles an hour; and their loss in velocity accordingly, being, at the end of the first 150 yards of level, at the rate of $1\frac{3}{4}$ miles an hour, as near as possible. This loss, then, I will allow for the passage of a train over a skeleton length of piping; and, deducting it from the final speed, $27\frac{1}{2}$, due to the end of a section of propulsion piping, I have for my final speed at the end of a section of skeleton, that of $25\frac{3}{4}$ miles an hour; and at this speed, it may be considered as entering the next propulsion pipe.

The speed mentioned in the above experiment, as that due at the commencement of the level, is some trifle higher than the driving speed I claim—whatever I may conclude, for reasons previously stated, it will prove to be in hydraulic propulsion—but, as the load, in the experiment alluded to, was so much lighter than those, it would seem reasonable to work, under so powerful a system, it strikes me it would appear almost like affectation, were I to propose making any deduction of speed, on this score; particularly as the experiment, from which I deduce my calculations, does not appear to have been one of the most favourable for my purpose, of those which Dr. Lardner undertook; though it is one in which all the requisite data are most distinctly given.

The figures in the preceding pages will now enable us to determine what the average speed will be, on the hydraulic system thus arranged, over an extent of railway; and this is at once found to be 26¼ miles an hour. If this very slight decline in speed, in producing an average, is worth consideration, it might easily—and where new railways were forming—economically, be avoided, by making each line a waiving one. It would be effected thus: let the gradiants usually be such, as that the trains shall ascend, along that part of a railway over which a section of propulsion-pipe extends, at the rate of, say one in 100, and descend at the rate of one in 200 over that, carrying a section of skeleton pipe; the gravity and momentum together, thus compensating, for the very trifling retardation, otherwise here experienced in the speed of a train. An ascent of one in 100, or even one in 50, I think it might easily be shown in figures—if I might further be allowed to detain my readers—would not sensibly affect the speed of a train over the propulsive piping, as the driving power there is so enormous. In fact, the gradients, which this system of propulsion would easily overcome, are of a character so dissimilar, in point of steepness from those we thus far ever have met with on railways, that I would rather leave it to others to describe them, than hazard the charge of exaggeration against this little pamphlet, by undertaking this on the present occasion. A calculation of this sort would be most simple. Deduct so much from the propelling power, as will be absorbed in meeting the retardation due to a given train at a given speed, and the

large remainder of the propulsive effect, may then be applied in overcoming the inclination of a train to gravitate on an incline. As the square of the speed up an unfavourable country, is reduced so, in like manner, and in like proportion, is the amount of propulsive effort, at the further extremity of a section of propulsion-piping, where the driving force has least available power, increased. A trifling decrease in speed, would here afford a great increase of power.

Hence, were it proposed, by the aid of hydraulic propulsion, to ascend what are termed "hill sides," if the speed were lowered a little, and also if the length of the sections of skeleton piping proportionally reduced, and those of the propulsion-piping equally increased—or, even in extreme cases, rendered continuous—can figures show, this could not be done? Deep cuttings might be altogether, or at the least, to a very considerable extent, dispensed with; and an immense amount might thus, in the first instance, be saved to shareholders, and ultimately to the public, by enabling the directors of railways to adopt a system of very moderate fares; and this again would re-act in favour of the shareholders, by, in all probability, much increasing the traffic.

In fact, the difficulty of rendering steep descents practicable and safe, would be greater on this system—as it would be on every other—than that of overcoming the ascents. No propulsive apparatus, of course, would be required for that line of the rails, which carried the descending train; and where the descent was not very considerable, the difficulty might be practically overcome, by the beautiful contrivance which is adopted in the celebrated Box tunnel, on the Great Western, near Bath; and in which, before such means were taken, the descent was found to be inconveniently steep. Where the descents were very rapid, it is possible the iron rails might be entirely dispensed with, and strong wooden longitudinal sleepers laid, in place of them, with deepish grooves cut in them, *to fit at the bottom, the vertical transverse section of the periphery of railway wheels*, and with steep slanting sides to such grooves. If this could be worked out in practice, it would oppose a very considerable friction to the progress of a train, which might otherwise gravitate too fast. Wh the wood had worn a little, such longitudinal wooden rails w be improved, as regards the object here in view, not deterio

It must not, however, be supposed that I urge this idea with any decided confidence in its practicability. I merely offer it as suggestion; with the full hope that something better, for remedying the difficulty, as respects the extreme cases, which I have proposed, may occur to more able and experienced mechanists; and with this observation, I leave the matter entirely open to consideration.

We are now arrived at that point, in this treatise, where we can properly investigate the character and effect of the propulsion-receivers.

It has been already stated, that the friction or retardation will increase in hydraulic propulsion, as the square of the velocity. Hence, if the speed required were a low one, the lengths of propulsion-piping might be increased in a much larger proportion than would be at first, likely to occur to the mind; in fact, to parody the celebrated sentence of the great mechanician of antiquity, an hydrostatic philosopher of the present times, might truly exclaim, "Give me but time, and I will send the power of water, under a vertical head, in piping, from one end of a county to another."

But as one of the first desiderata in any railway system, is to overcome time as well as space, the laws of hydrostatics require that, to preserve velocity, the propulsion-pipes should be comparatively short; and it has only been by combining, under the requisite conditions, the apparently dissimilar action of two leading principles in hydrostatics—slowness and extended operation, and velocity and contracted operation—that I have felt myself enabled to offer to the public, a practical and powerful system of hydraulic propulsion.

From all that has preceded, it appears reasonable, that a propulsive-pipe should not be shorter than 50 yards, nor longer, for the higher speeds, than 100. Well, then, thus far I show a train practically driven over some 70 yards of propulsion-pipe, and about some two or three hundred more of skeleton pipe, and that is all. The great inquiry now comes:—Can this mode of action, by any manifest and simple means, be con[illegible] is inq[illegible]
I answer by the f[illegible] of
in piping is ve[illegible]
in fact, at l[illegible]

nothing. Call this principle, then, into action, by placing by the side of the railway, at the end of the first section of skeleton piping, a wrought-iron air and water-tight receiver, of sufficient capacity to contain rather more than that volume of water, which would fill a section of propulsion-pipe, and, over that, a much larger volume of air, let this volume of air, which is to press on the water in the receiver, being there condensed by a small hand air-pump, or any other convenient apparatus—for the means of doing this are not material, as it would not be likely to require repeating—and let this condensation of the air be raised to a pressure of six atmospheres: let the space within the receiver, so occupied, be equal to five times that which contains in bulk, one section of propulsion water; that is, when the vessel is duly charged. Now, let the power, at the first power station, occupy itself, when it has nothing else to do, that is, when no train is passing, by throwing into this receiver—*slowly*, so as nearly to obviate friction—one propulsion section of water, through the medium of an extra pipe, of smaller bore, provided for this purpose. Let there be also a short pipe, connecting this receiver with one end of a section of propulsion-piping—just as would be the case at a first power station; let this pipe be of the same bore as the propulsion-piping—or it might advantageously be a little larger, if, at its junction with the propulsion-pipe, it presented a conical-shaped termination. Now, the propulsion receiver being duly "charged" with water, under a pressure of six atmospheres, open a valve in this connecting pipe, and what happens? The water in the receiver, instantly shoots up the propulsion-pipe, *under a pressure of six atmospheres.* Does it so continue to the end of the pipe? No. The space above the water in the receiver occupied by the compressed air, which, before the valve was opened, was equal to five volumes of the water now discharging, will, by that discharge, ultimately become equal to six such volumes; and the pressure, which, in the first instance, was 6×5 will then become 5×6. This alteration in the pressure will clearly be gradual, and the change will be complete, just as the
...on valve in the connecting pipe, closes again, on the
...e having received its due charge of water. This
...r to every one, the propriety in working the pro-
...of starting the water, as in the preceding ...

When a propulsion-receiver has delivered its charge, the superabundant pressure of the air within it, will be equal only to that of five atmospheres; *that* is the most favourable point for the present work of re-charging; but let us go to the least favourable, and suppose the same receiver is taking back its water, and has received very nearly its whole charge; it will then present an air-spring, opposing the ingress of the water, equal to a pressure of six atmospheres. If then, I had no more than the same pressure available at the first power station, one power, that of the steam engine or vertical column, (as the case might be) would be exactly counterbalanced by the other power or pressure, namely, that in the propulsion-receivers; and the work would consequently stop. The reason for preserving a constant available power of 6½ atmospheres in the machinery, at the first power stations, will now be most apparent; and it will also be clear that, this *constant* power will be required to overcome an opposing power, varying from five to six atmospheres—the length of time it will take in doing this, in the several circumstances, in which it will be required to accomplish it, will be minutely stated, a little further on.

Now, to preserve all the clearness and simplicity possible in these calculations, let us revert to the power, load, or pressure, which in a former part of this pamphlet, was found to be due under 6 atmospheres, to the area of the propulsion-pipe; then we will add to that power, the pressure and load due to the extra half atmosphere, (equal to 16½ feet of water, vertical) and of the amount so obtained, we will take two thirds, and set the same down as the free impulsive power, which, it has just been explained, the engine must exert. We shall then consider what proportion this power bears, with that we have already assigned to the engine, and so we shall pass on to determine the time it will take on each occasion to accomplish the work, which it will be required to perform.

The pressure, or available force of six atmospheres, upon an area of one foot, (that of the propulsion-pipe,) is 86 cwt. 2 qrs. 14 lbs.; t[illegible]h, add the pressure of an extra half atmosphere, (7 cwt. [illegible] lbs.), and we have, as the whole gravitating po[illegible]pheres, 93 cwt. 3 qrs. 10 lbs. Now, take ⅔ of [illegible] find, 62 cwt. 2 qrs. 7 lbs. will be the free power

which I shall show the steam engine will be required to exert. This, in fact, represents the gravitating power of $6\frac{1}{2}$ atmospheres of water, when pressing on an area, $\frac{2}{3}$ that of the propulsion-pipe, and the engine will have to perform the work of such gravitating power; but it has already been shown that an engine of 50 horse power, exerts, with ease, at its ordinary work, a moving force equal to 66 cwt. 3 qrs. 24 lbs. There will, therefore, remain in the engine, unapplied, an amount of force equal to 403 lbs.—nearly three horse power; but as it is desirable that the machine should have a light, rather than a full load, I shall not propose to reduce the horse-power of the engine.

It now remains for us to consider, in connection with the present subject, the number of propulsion-receivers, such an engine can charge within a given interval; and this will give us the length of railway, over which such a machine will have to afford propulsive power to the water.

It appears a reasonable thing to assume, that a working railway day on any extensive line, will consist of 16 hours; and if the trains were large—as they might be advantageously on this system—the day traffic might probably, with very few exceptions, be performed conveniently with 24 trains. Now, this number of trains, divided over a space of 16 hours, would allow an interval of 40 minutes between the passing of each. Within such an interval then, the 50 horse engine must complete each series of its work. That series, I find, will comprise the charging of 19 propulsion-receivers; that is, nine on each side of the engine, and one immediately before it. This last will be requisite, as the engine itself will not force the water forward with anything like that velocity at which it must be worked. The engine will accumulate power comparatively slowly, and the propulsion-receivers, throw it forward at a great velocity; and this, for reasons already given, when referring to the action of two great laws in hydrostatics. The object in view, in the last named receiver, which would here stand immediately in front of the engine, may however, be obtained conveniently enough in the air vessel, through the agency of which, I have mentioned the en preserve a constant stream of water flowing up the recei pipes; this I now propose, shall act also as a propulsion This receiver and air-vessel conjoined, therefore, has t

When a propulsion-receiver has delivered its charge, th... of
abundant pressure of the air within it, will be equal ... articu-
of five atmospheres; *that* is the most favourable ... sion water
present work of re-charging; but let us go to ... he receivers
able, and suppose the same receiver is taking ... ence doing as
has received very nearly its whole charge ... ly point requir-
an air-spring, opposing the ingress of ... o double work—
pressure of six atmospheres. If ther ... duties at the same
same pressure available at the firs ... h it must be equal to the
that of the steam engine or verti ... ssel of the engine, be under
be) would be exactly counterb ... ter also, it must be made of extra
pressure, namely, that in the ... of the full ordinary thickness for
would consequently stop. ... ⅜ of an inch; for the water from the
available power of 6½ at ... ter it with a sort of rush or shock, very
power stations, will n ... ar stream in which, through this same
clear that, this *cons* ... eyed into the other propulsion-receivers.
opposing power, ... ine, we are at present considering, will only
of time it will ... the water forward, up the two branches of
in which it ... as that we suppose in connection with it, at the
stated, a li ... per minute—that being the average steam en-
Now, ... But a propulsion-pipe contains 210 cylindrical feet
these c ... and as the area of the feed-pipe is only ⅓ of that of a
which ... pipe, this content of 210 feet of water will, in the
und ... be extended over three times that length, or 630 feet;
wi ... is the length of the column of water of the reduced area,
h ... the engine must throw into each of the receivers—charg-
... pair of them together, on account of the diminished area
... the horizontal column—to constitute a full charge for each
section of propulsion-pipe. Now, the lifting or forcing forward
of any thing, which is a load for an engine, over a distance of
630 feet, is very nearly three minutes average work for such
engine, and the *two* columns of water, which the engine has to
throw up the feed-pipes, right and left of it, constitute such a
load. Hence, if the retardation of the water in the feed-
pipes was so far overcome, by the preponderation of the column
of water, or an equivalent load, in favour of the engine, as to
allow of the liquid being passed up these pipes at a much higher
..., *the engine* could not, under the explained conditions,
...sh *it. It would*, however, be very different when these

ere charged from a vertical column of water; for that able of almost any speed which the retardation and wherever such a column can be found, ivers, which are least removed from the first e charged accordingly, much more quickly n engine, certainly, might be adjusted to ent arrangement; but the better method ease the speed of the water, but the size of that is, if this were ever required; in either r, a proportionably increased engine power would ate.

w, as I have stated that the engine must take as its load a ouble column of water, of seven inches in diameter, and force it up the two branches of the feed-pipe, it follows, as a steam engine can lift or push its load 660 feet in three minutes, that, appointing the engine in question to charge a pair of propulsion-receivers—being equidistant from it, on the right and left hand—with 630 longitudinal feet of such double column of water, would constitute a short three minutes work for the engine; provided its free action, at that speed, were not affected by any retardation in the pipes. Thus—bearing this process in mind—the engine, having to charge one propulsion-receiver standing directly in front of it, and nine pairs on each side of it, will be able to accomplish this series of work within thirty minutes. But this apparent result must be qualified in the following manner: first, the single receiver, taking, through a pipe of proper bore, the whole water, from the engine till its own charge is complete, will be charged in half the time that a pair would require, that is, in $1\frac{1}{2}$ minutes—or something less, if we took the power of the machine at its full average working rate—next the six pairs, nearest the engine will be charged in the time just stated as due to the work $(6 + 3 = 18)$ for the retardation due water travelling up to a pipe of seven inches bore, at the very low velocity of 220 feet per minute, is too small to retard the work within that length of pipe, which will reach to the sixth pair of receivers—each of which will be placed at a distance of 1,320 yards from the engine;—then, the seventh pair—220 yards further removed—will be charged in three minutes and 17 *seconds; the eighth* pair—220 ya tes *and 30 seconds*; and lastly, by tl ore

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… will be charged in three minutes and 37 seconds. The … in exact accordance with Tredgold's formula. When … the retardation, under the preceding conditions, has be… to impair the given first speed, its effects are estimated … ; and, as in all previous cases, without claiming any a… for the momentum due to these extended movi… columns of water.

To recapitulate the preceding results; we have—

	Min.	Sec.
One propulsion-receiver charged in	1	30
Six pairs of do. do. do.	18	0
One do. do. do. do.	3	17
One do. do. do. do.	3	30
One do. do. do. do.	3	41
Time required to charge propulsion-receivers for 2¼ miles of rails	29	58

Thus, though I have made the preceding calculations, for th… propulsion power being required about once in forty minute… it appears highly probable that a 50 horse engine might driv… a train over an extended length of railway, once every half hou… if there were occasion. The nature of the propulsive agen… ensures great regularity as regards time, and the momentum … the very powerful columns of water, both in the propulsion an… feed-pipes, appear very likely to cause all the work to be accom… plished at a more rapid rate than I have, in this pamphlet, s… forward in my calculations, as being due to it. Should an… enormous amount of power, in considering future prospects, b… thought desirable for any of the greater lines, feed-pipes of 9 inches diameter might be charged, for the length of line I hav… considered as under the action of each first power station, in 1… *minutes;* or the length of line acted upon by each power statio… might be extended to three miles, when such feed-pipes would tak… *22 minutes* to charge them; but pipes of this diameter would requi… a power equal to, from 70 to 75 horse, to work them with full effec… Before I dismiss this subject of speed, in its various proportion… I may here be allowed to allude … present speed in th… locomotive … h the anticipatio… or … brough… … is ce… , in

first edition of the work, in 1825, he mentioned that 40 tons conveyed six miles an hour, was then the performance of the best locomotives; and he adds, "in 1829, according to the table given by Messrs. Walker and Rastrick, they fixed 48½ tons, conveyed ten miles an hour, as the highest performance the directors of the Liverpool Railway could expect for their engines!"—*Third edition*, p. 547.

The length of railway over which 19 propulsion-receivers will drive the trains, is very easily estimated. Calculating from the centre one, there will be nine receivers on each side of it, with an interval between each of ⅛ of a mile; and a like interval will be found between the last receiver of one first power station, and the last one of the next: (see drawing); thus these 19 receivers will propel the trains over two miles and three-eights of the railway; and this not over one, but over both lines of rails; for with the exception of the propulsion and skeleton piping, and a few valves, &c. for the second line of rails, it will not occasion much more expense to establish this system of hydraulic propulsion on a double railway—one of the ordinary arrangement—than on a single one; which with a large traffic would be most inconvenient, if not absolutely impracticable. The same driving force at the first power stations, and the same propulsion-receivers and feed-pipes, with their valves, would do a very large amount of work on a double line, as well, and in fact with more facility, than on a single one; and, as respects propulsive effort, 2⅜ miles of double line, are equal to 4¾ of single line.

I believe I have not yet mentioned the night-work, which usually implies the passage of the luggage trains. Under the present system, these travel, from motives of economy, at a much slower speed than the passenger trains. Mr. Wood, in his work, estimates that a locomotive engine which, at 20 miles an hour, can drag 98¼ tons, at 30 miles an hour, will *only draw 27 tons*! With hydraulic propulsion, there would be *no occasion for this* great loss both of speed and time. From my estimate of the duration of a railway day, it will appear there are eight hours left for night; and within this interval, 12 luggage trains at least might be conveniently passed over a railway. I am not aware of any line that has to afford conveyance for this number of be

luggage trains nightly; there are, however, occasionally night mail trains; and these might take their share of propulsion among the rest.

It will be perceived, that in the latter pages of this little work, I have viewed the drawing power for the system, nearly as if the steam engine was the only source from which I could derive a first motion. This I have done for two reasons: first, it has been objected against hydraulic propulsion, that vertical heads of water of requisite altitude, will seldom be available. As regards many lines—or a considerable portion of them—I admit this objection in its full force; and as regards others, I admit it with two qualifications; the first is, that wherever railways now formed, pass under the spurs of hills, or through them by tunnels, there will be occasional opportunities, more or less frequent, according to circumstances, of taking advantage of good powerful heads of water, of at least $6\frac{1}{2}$ atmospheres, hydraulic altitude, —214 feet—and when they *can* be found, economy dictates their useful application; and that they will occur more frequently than might at first be imagined, appears probable enough, when we bear in mind, that those lower elevations, near which, railways occasionally pass, are frequently the abutments of higher hills; and without going a quarter of the distance, that water-works Companies sometimes fetch their water, when offered them under such inducements; and by the aid of supply receptacles, extremely small when compared with their dams, I cannot but think the quantity of power economically to be derived from such sources, will be very far from contemptible. My second qualification to the objection, is stronger still. It applies to lines that may be formed with a view to availing themselves of hydraulic power. These will naturally seek the vallies among the hills and mountains, and court the contiguity of high grounds, which elevations must often furnish abundant hydraulic power, to overcome with ease the undulation of the country, and to drive a large traffic at a very trifling cost indeed. I hardly need say, that there can be no binding necessity for the first power stations being distant from each other exactly $2\frac{3}{8}$ miles. Good falls of water would at any time, to a certain extent, influence their locality, and whenever one presented itself, any where between two and three miles from the last station,

would be fixed upon as the spot for the next. But whatever advantages may ultimately accrue to the system from such sources, the whole tenor of this pamphlet, I trust has made it apparent, that I do not consider hydraulic propulsion should look for that success which I think it deserves, mainly for the frequent aid of natural vertical heads of water; and this, particularly in the case of railways already formed. I think I have already shown, it has very great power independent of such aid; and it will remain for me, in the same circumstances, to prove its great economy.

I must now explain the second reason, for which I have latterly viewed the steam engine, as nearly the only first agent for charging the propulsion-receivers. It is this; the steam engine has become throughout the country so perfectly the popular representative of power, that when a working force has to be estimated, it is most conveniently done through the medium of this deservedly popular machine. But then it should, at the same time, never be forgotten that there are many other machines. Water wheels, Barker's mills, and those powerful water machines of the steam engine construction, as respects cylinder and valves, which bear the name of hydraulic engines, might all occasionally be brought in to aid the working out of this system, with powerful effect, and with a view to its most economical arrangement. A low fall of water, if of sufficient volume, will drive almost any hydraulic machine, so as to do the work of a steam engine, without the cost in fuel. To such an extent might this principle be sometimes carried on railways, as to cause one stream of water to do, in a manner double work. Thus, a stream conducted down from the head of a deep cutting, might first work a water-wheel, for instance, on the level of the railway; and, afterwards, the same stream of water might be conducted some distance, in a proper channel, along one side of the line, till brought to the top of a high embankment, down which it might be thrown upon a wheel beneath with considerable effect. The power from the water wheel, would, with much ease, be brought up again to level of the railway, to be there applied upon a contiguous power station: hence, many advantages may be expected accrue *to this system*, which will not show themselves *of the calculations.*

luggage [illegible]
mail trains [illegible]
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influence their locality, [illegible] into the cleft; and
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square inch there can be no doubt whatever that the pipe will be then perfectly water-tight; that, in fact, for the time being, it will be most effectually corked. Now, on account of this wedging of the valve, it is possible it may occasionally not fall down into the bottom of the pipe, as I have anticipated, even though the formation of the cleft is such, as to make it appear difficult for it to retain the valve, when a pressure underneath no longer exists. But, supposing this to take place, the machinery is also arranged to meet the contingency. The arrangement is most simple; it consists of two small pulley wheels, attached to the driving truck, and placed one before the other, a little in front of the power-connecting-plate, in such a manner as first to loosen the valve in the cleft, and then to put it down; when it will be in a most convenient position for sliding along the upper part of the guide-neck, and so taking its place in the cleft again above the piston.

The materials of which this continuous valve should be composed, and the manner of its formation, must be explained: and first of its formation: let it be done thus; form a mould, say of clay or plaster of Paris, whose transverse area shall be the same as that of the valve, to be constructed; and within this mould, before it is completed, stretch well apart, a series of small strands of wire rope, or strong single wires, longitudinally; then, transversely, fully half fill it in a systematic manner, with short and moderately thin bits of very hard wood or whalebone, of the same length as its transverse section, in the different parts of it, where the wood is placed. When all this is well arranged, the material for filling up the insterstices, only remains to be pointed out and applied; this is caoutchouc or India rubber; which in a liquid state, must be poured in, to fill the mould. It will now, therefore, be evident that the intention is to *cast* the continuous flexible valve in a mould. When dry, the valve is made and ready for use. The wire strands will prevent the continuous valve from stretching longitudinally; and the h[illegible] wood or whalebone, will prevent it from contracting tran[illegible] in any inconvenient degree, when subjected to th[illegible] sure, which it will be required to sustain.

It will be observed, that a stout wire is made to [illegible] *tion of skeleton*-pipe, just the same as the co[illegible]

does through one of the propulsion-pipes; in fact, the valve and rope, being always linked together, keep up one unbroken line. This is merely to preserve the connection between one section of continuous valve and another. The wire rope will consequently pass over the guide-neck and piston, as the train goes by, in the same manner, but more loosely, than the continuous valve itself does. The whole of this apparatus will require, before being put intouse, to be subjected to a great tension, to prevent after-stretching. It will then work with great truth, as there will be seldom where more than about seventy yards of the continuous valve, or 150 of the wire-rope, exposed at once to any draft or pulling from the travelling piston—small, though it will be—for each length of the continuous valve, when fixed in the cleft, by the water pressure under it, will be quite immoveable, and will constitute a strong holding power, which will not be wholly relaxed, till some time after the travelling piston has passed over the adjoining section of skeleton, and entered the next of propulsion-piping. The power-connection-plate should be two feet in breadth, and $\frac{3}{4}$ or one inch in thickness, which will leave nearly an inch play in the cleft, on each side of it. These proportions will combine great strength, without any inconvenient degree of thickness.

There is a peculiarity in the formation of the piston, which nearly obviates the whole of the friction, that might very naturally be supposed to be due to such an apparatus, when travelling within a confined space, at a speed of nearly thirty miles an hour. The piston must, of course, be formed of the best wrought-iron. This will allow of its being made with a view (comparatively) to lightness, particularly in the feather extending below, on each side of its guide-neck, without sacrificing that requisite degree of strength, which should distinguish the apparatus.

Now, no part of this iron piston ever touches the propulsion or skeleton pipes, up which it moves; some rings of leather, or India rubber, which are fastened down to it on one side and quite loose on the other, only coming in contact with the sides of the propulsion-pipe. The piston is supported vertically behind, by one pulley or friction wheel, and before, by a pair—between which the continuous valv[illegible] he vertical line, it is evident the [illegible] fact,

it runs upon wheels within it. In this direction, however, it approaches nearest to the pipe at its forehead, just above the arch-way, through the power-connection plate; but, even here, it should be fully half an inch below the pipe. In the horizontal direction, it is protected from ever rubbing or drawing against the sides of the pipe, by another friction wheel, placed forward, to guide it as truly in that direction, as the others will in the vertical. This horizontal pulley wheel, it may be remarked, is placed, as well as the vertical pair, in the guide-neck; but this, in speaking in general terms, must be understood as included in the common designation of piston. Now, the piston itself, that is the latter barrel, or cone-formed portion of the apparatus, will, as may be perceived by the drawing, approach in no direction, within 1¼ or 1½ inches of the sides of the pipe. This statement at once renders it incumbent on me to explain how its requisite water-tight quality will be obtained. A series of rings of leather, or of caoutchouc, of a breadth of about four inches, are to be well rivetted down to it on one side—that nearest the guide-neck—and on the other, are left perfectly free; thus, if a very powerful blast were blown up the pipe, behind the piston, three or four of the last of these rings would expand, or open on their loose sides, with which they would then press against the sides of the pipe, and, consequently, would intercept the current. The very same thing will occur when the propulsion water presses on them from behind, with this difference only, that, as the liquid will wet them, they will more effectually, and with more facility, prevent its pressing on further, than say, the fourth or fifth ring; or, if it ever should be getting a little more forward, the slight chatter, or quick, but almost imperceptible shaking of the apparatus, as it rushes on at a great velocity, will, very quickly, throw it back. The most easy way of imagining the working of these rings, and the manner they will be thrown open by the liquid is, by recalling to mind, the opening motion in the water, of the gills of a fish. I think this series of rings, say, of caoutchouc, may very properly be termed the piston-gills.

The nature of the preceding remarks will make it very clear, there can be no occasion to bore the propulsion-pipes. Let them be well cast, with plaster of Paris, or other good cores, and the boring of them would, I imagine, become a most s

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rather remarkable, that [illegible] current, and
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than any other part of [illegible] its own gra-
arises from the valve [illegible] self from the
power-propulsion plate, [illegible] propulsion-pipe,
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occasions, been made to [illegible]

[illegible] propulsion-pipe;
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the quick, or tardy opening of the communication, and the stop-valves will be reversed. The seat of the communication valve, if inclined at all, will then be in the other direction, and its projecting leaf, which is to assist in throwing the valve up, will be made lighter, so that the mere pressure of the horizontal column of water of one foot in height—when the great vertical supply or pressure has been cut off—shall hold the valve to its seat for a short interval, while the stop valve, with (in that case) a greater gravitating power in it, shall be thrown open, and the water, be proceeding to discharge itself at that end of the pipe. This discharged water will frequently be allowed to run to waste; but where the supply is not superabundant, and where a steam engine, or other machinery, is fixed at a first power station, it will be occasionally run back thither, either through the drains already formed on the railways, to keep them dry, or through other short ones, to be added for this express purpose.

The globe valves of the air-vessels will be also found to be self-acting; and will discharge the water, shot up into these vessels from the propulsion-pipes, very gently into any channels that may be arranged for conducting it away. The two valves, connected with each of the propulsion-receivers, will be found to be also of the same character; being self-acting, through the same simple medium, namely that of the floating globe; and they are arranged with a stirrup, in order to open and close quickly; that is, towards the end of every up or down move of the floating globe on its lever, as it rises and falls with the water. This will be found to be desirable for the proper working of the engine, whenever that machine constitutes the first acting power.

I may here mention, that the man-holes in the air-vessels and propulsion-receivers, which, in the drawing, are represented as opening outwardly, should in practice open inwardly, to render the air-pressure in those vessels available, towards the perfect closing of these man-holes.

The air-valve in the propulsion-pipe, will be only required in case it is found the continuous flexible valve does not always fall to the bottom of the driving-pipe, when the water is drawn off. In that case, this valve, will permit the free discharge of the ai which *otherwise would*, as the piston advanced, become co *pressed in the pipe*—from its being then closed in front, by

flexible valve—until it might, eventually, even stop the train. But whether this valve will be found in practice, to be requisite or not, its pulley and leverage will be always required; as they also act, through the long connecting rod, which is exhibited as broken off, in the drawing, as reversing machinery for the communication valve. The leverage of this air-valve takes, through its pulley, a rise of eight inches, which it derives from the inclined plane on the driving truck; and it conveys this movement forward—multiplied by the relative proportions of the two arms of its bell-crank—to the communication valve, which—by its action being reversed—it closes with a fall of 14 inches.

The stop-valve, at the further end of a propulsion section, to arrest the progress of the water up that pipe, and turn it into the air-vessel, is to be closed, as it will be observed, by a traddle. This traddle is worked by the front pair of pulley-wheels, carrying the travelling piston; it has a shallow bed or recess in the bottom of the skeleton piping, where it is placed, and into which it falls, when the pair of pulleys throw it down; and, in doing this, throw up the stop-valve. The length of this traddle is three feet six inches; its fall is seven inches, and the lift, carried through the leverage of its bell-cranks upon the stop-valve, is 14 inches; being the full rise of that valve. The traddle will require its seat placing at such a distance in the skeleton, from the stop-valve, as may allow of the piston having wholly passed through, before this traddle begins to act. It has been before explained, that the stop-valve will, by its own gravity, fall, and thus again open the end of the propulsion-pipe—which it is only required to hold closed, while the propulsion-current is rushing up and exhausting itself in the air-vessel—as soon as the tide is turned, as I must beg leave to express it, and the water is drawing off. Now, while I feel the conviction strongly, that the machinery of this valve and the arrangement of its gravity, are good, and fully trustworthy for general purposes; yet I must admit, this valve does not possess that unerring certainty of action, which, I feel assured, attaches to the machinery of the interception valve; I admit too, that all railway machinery should be [illegible] human foresight can make it so—quite un-

[illegible] inery of this stop valve to that cha-

racter, I propose to add to it an additional lever, *solely* to guard against the possibility of the valve sticking to its seat, when the pressure of the water against it is withdrawn, and of its not falling by its own gravity, as it then ought to do. The lever and stirrup, which are to accomplish this, will move backward and forward in the space between the air and stop valves, as the machinery to which they are connected, guides them, and neither doing good nor harm, unless the very remote possibility, on which we are now calculating, of the stop-valve having adhered to its seat, should actually take place, when this leverage will certainly, throw it down, and open the orifice, or area, of the propulsion-pipe, which it closes. I have not arranged this lever for exhibiting any great degree of strength; for a very slight force would manifestly throw the stop-valve down, *if* it ever stuck: for the same reason I have consented to place the lever rather obliquely, with reference to its line of work, one of its arms reaching under the skeleton pipe, and the other, the outside of the rail, in the same line with that of the bell-crank lever of the air-valve. If either the proportion of strength assigned to this lever, or its relative position, is objected to, nothing can be clearer than that a little more metal can be worked up in it; or that, by lengthening its axis till it assume the shape outwardly of a thick short pipe, and by separating its two arms—so that one shall be attached to each end of that axis—any degree of strength, and strict engineering accuracy of arrangement, can be given to this precautionary machinery; the difference being only, that it will occasion a little extra cost, but not much; and, probably, without occasion.

The mode of passing a train from one railway to another, at the junctions, and from one line of rails to another, at the crossings, will require a little explanation; and it will be the more easily given, as the same principle is in operation on both occasions.

The skeleton piping will afford to the hydraulic system great facilities at such places, which will always require to be passed over on a section of that description, where the propulsive water never comes; and the laying down and proportioning the *propulsion and skeleton* piping, on a railway—by small additions *to, or subtractions* from, the respective lengths which any given

locality might otherwise prescribe for these pipes—so that a section of much more than the average length shall terminate at a crossing, or immediately beyond it, could never be lost sight of by an engineer. It will require a considerable section of line, beyond the last propulsion-pipe, to allow the impetus, then in the train, to die away, and the speed to be reduced to that, which is usually esteemed safe and proper; particularly at the short crossings, adjoining stations. Sections of skeleton, to terminate at, or near such localities should be at least 300 yards in length, except where an incline is interposed, of sufficient gradients, materially to reduce the speed of an approaching train.

When two lines of rails meet, at junctions, crossings, or sidings, a train on the locomotive system, is enabled, by the proper adjustment of the switches, to pass on to either; but this requires a man being constantly stationed on the spot, to work those switches, or points. This individual would be a very useful person on an hydraulic line, as not only the switches would require fixing—which employment occupies usually but a very small portion of his time—but also *the junctions of the wire rope*; which rope, as it is to extend along each section of skeleton, must evidently join, where there is a junction of pipes and rails. These junctions of rope are easily to be effected. At the end of one portion of the rope, at the junction, make a loop, and fortify it against friction, by having previously wrapped the rope with a strong iron wire strand: at the end of the other portion of the rope, attach a long narrow hook, shaped nearly like a loop; that is, with the end bent down till it nearly meets the shank, and only affording sufficient opening for detaching it from the loop, on the previously mentioned portion of the rope. Now, for the present, let it be supposed, this rope extends along the straight line of rails—not the crossing. Let it be also supposed there may be some occasion for here dividing the rope. In that case, the man, who has to do this, must be provided with a strong instrument, shaped like a pair of the largest garden shears; but which, at the end of each of the shorter arms of this double lever, must possess two fingers, or bent fangs, to take the wire rope between them, and so as to clasp each end of it, where the loop and the hook are [illegible] With this instrument, the [illegible] stretch[illegible]

rope a little nearer together, which would loose it at the junction; and who then would be enabled, with much facility, to detach the hook from the loop. Now, instead of *one* such hook, let us suppose there are two attached to the loop; that is, the one we have already supposed as belonging to the straight line of rails, and another, which we must now imagine as terminating the end of the wire rope, belonging to the skeleton pipe of the crossing, and here joining that which we have been previously considering. The man here in charge of the line, would merely have to detach the loop of that part of the rope, which belonged to that branch of the line, for which he was about to set the switches for the train not to run on, and his work would be done—or rather, nearly done; for the detached portion of the rope would require to be kept in a sufficient, moderate state of tention, for the convenience of afterwards attaching it again. This would be immediately accomplished, by affixing it to one end of a moveable stout double hook or S, the other end of which, would be temporarily held in any proper opening, cut into the skeleton-pipe for that purpose: or a moveable bracket might be easily contrived to answer the same purpose as this double hook.

In the previous remarks, on joining the wire ropes, it must be clearly understood, that, the loop and hook must not be too large together, to pass with the greatest ease, through the small archway, rising out of the guide-neck of the travelling piston. As iron is the only material to be used, which combines great tenacity with smallness in bulk, this will be arranged without any difficulty.

There is one point, at which the nice adjusting of the wire rope, between tension and laxity, may require practical experience for its perfect arrangement; and that is, at the short slidings and crossings which are frequently to be met with, at the stations, particularly the larger ones. The rope in such cases, will not lie stretched along the middle of the skeleton pipe, as it ought to do, for its being taken up with perfect facility, by the guide-neck of the piston; on the contrary, it will lie along the bottom, inclined a trifle from the centre, and bending a little towards that of the pipe, next the inside of the curve. But, as at all re speed is low, there will be little or no difficu It will be only necessary, as above intima

[illegible] rope to the circumstances of the case. Easing it [illegible] more than would be desirable for the higher speeds, [illegible] be required. As regards the curves, which occur [illegible] lines, where the higher speeds are used, [illegible] very wide sweeps as generally to be imper- [illegible] unless it trace them into the distance. The [illegible] wire rope, therefore from the middle of the [illegible] ton pipe, over an extent—so very small, [illegible] the curve—as that of only 150 yards, [illegible] early as nothing; and the very slight side [illegible] ccur, in the wire rope sliding up the guide- [illegible] way on the piston, would be fully [illegible] always having a tendency to draw the [illegible] middle of the rails, and not leaving [illegible] on the outside of the curve, as [illegible] occasions much friction, with a [illegible]

[illegible] water would not answer for propul- [illegible] but if impregnated with salt, and [illegible] never congeal by any fall of temper- [illegible]. From this no material expense [illegible] run back again to the power [illegible] water would at other seasons; [illegible] gement of drains. From these [illegible] over and over again, with small [illegible] while the frost lasted. A weak [illegible] the congealing power of any [illegible] requisite, fully to saturate the [illegible] material, since the duty [illegible] article. The wise policy, [illegible] restored the natural order of [illegible]: which is not only one of [illegible] several of the arts, but [illegible]. After becoming the [illegible] which extensive trades have [illegible] improbable it may extend its [illegible] successfully aid hydraulic rail- [illegible] locomotion is thrown [illegible] if not hel[illegible] by

the severity of the water. Thus, when the driving-wheels of a locomotive engine cannot bite the rail, and whirl round, with the greatest rapidity, without advancing, the hydraulic system —assisted, instead of being retarded, by the hard ice on the rails, which will give a finer surface—will, with brine in its pipes, be enabled to preserve as much regularity in the time of the arrival of its trains and mails, as during the finest weather. In short, the hydraulic system is not likely to know anything of the seasons; it will not be affected in its operations by them.

CHAPTER VIII.

It is time I hastened to draw this pamphlet towards its conclusion. I think I have said enough, not only to demonstrate the practicability of hydraulic propulsion on railways, but also, to show that its application on them would be attended with a great encrease of driving power; and now, when I have made an estimate of the first cost of establishing this system of propulsion on a railway, and also of the annual cost of working it afterwards, my undertaking will be nearly completed. I think I shall then have done my duty to the public. Beyond a certain extent, the public cannot expect even a patentee to go; and, in justice, they ought not; for if an invention—particularly, if of magnitude—becomes successful, it is not to the patentee, but to the public usually, that the lion's share of the advantage falls.

I have, in a previous part of the pamphlet, proposed, that each first-power-station shall work both lines of rails; over an extent of railway, two miles and three-eighths in length. I have also proposed to use steam wherever water power is not to be found; and, I have intimated that on many lines, I should find it necessary, frequently to have recourse to steam. I shall now, under these conditions, proceed with my calculation of the first cost of laying down, on $2\frac{3}{8}$ miles of railway, the whole of the hydraulic machinery, necessary for working that distance. I shall also, to be on the safe side, assume that such part of any given railway, must be worked by a steam engine. Wherever a locality occurred, which was favourable for a supply of water, the difference between the expense of a steam engine, and that of the piping to bring down the vertical column of water, or of hydraulic machinery, if the head of water had not an elevation of 214 feet, would be easily estimated; and that, according to the circumstances of each particular case. In like manner, nothing will be more simple, if it should be desired, than to ascertain the first cost of any part of the [illegible]
in the following calculation, for [illegible]
be only requisite to take [illegible]

Calculation of the first cost of establishing hydraulic propulsion over $2\frac{3}{8}$ miles of railway.

Steam Engine, of Cornish construction of 50 horse power, with boilers complete, at £23 per horse.........	£1150	0	0
Engine house, with foundations and chimney, complete	350	0	0
Propulsion-piping, for 38 sections, of 70 yards each (including both lines of rails) of twelve-inch bore, and one inch in thickness, with girths and holdfasts placed every four feet; say gross weight per yard 4 cwt. 2 qrs. 20 lbs., at 7s. per cwt.; then $38 \times 70 \times 4.2.20 \times 7s. =$	4352	5	0
Branch-connecting pipes from first-power-stations and propulsion-receivers for the above; say average, for both lines of rails, $\frac{1}{7}$ the first cost of the above	622	0	0
Skeleton-piping (half-piping, with longitudinal openings along its sides) for 38 sections of 150 yards each, for the pulley wheels of the travelling piston to run upon; say $\frac{5}{8}$ in thickness, and of gross weight of 1 cwt. 2 qrs. 0 lbs. per yard, complete; then $38 \times 50 \times 1.2.0 \times 7s. =$	2992	10	0
Propulsion-receivers feed-pipes of seven inches bore, and $\frac{3}{4}$ inches in thickness, for $2\frac{1}{4}$ miles (3,960 yards) $\frac{1}{8}$ of a mile in each first power division of a railway (*i. e.* the space between one division and another) not requiring this piping. This piping complete will weight 1 cwt. 2 qrs. 17 lbs. per yard; then $3960 \times 1.2.17 \times 7s. =$	2289	7	6
Two travelling pistons with guide-necks, of the best wrought iron, together, 8 cwt. 0 qrs. 0 lbs. at £3. 10s. per cwt.	28	0	0
Two pairs of springs, with power-connection-plates and iron straps or shackles, for connecting the above named pistons with driving trucks. (N.B. Driving trucks are not charged in this estimate, as they carry loads, the same as other trucks)	50	0	0
Two Travelling inclines, for two driving trucks, with stays to slot and levers, weight of each complete, 2 cwt. 2 qrs. 0 lb., say 5 cwt. 0 qrs. 0 lb., at £2. 10s. per cwt.	12	10	0
Two piston valves, with motion rods.	16	0	0
Valve machinery for thirty-eight sections of propulsion-pipe; say for each section, machinery £46., and four valves and boxes £24., therefore 70×38 ...	2660	0	0
Continuous flexible valve for each section of propulsion-pipe, £10. 10s.; and wire rope for each section of skeleton £2. 10., therefore $10\ 10 + 2\ 10 \times 38$.........	494	0	0
Jointing and fixing pipes, and putting down machinery per mile, £240; therefore, for $2\frac{3}{8}$ miles	570	0	0

Carried forward............£15,586 12

Brought forward............	£15,586	12	6
Allow for bolts, and sundries in general, per mile £200; therefore, 2⅜ miles	475	0	0
Propulsion receivers, weighing three tons each, say, with floating globe, &c., £60 each, therefore, 19 × 60	1140	0	0
Air vessels, about 9 cwt each, say, with branch pipes to them, and floating globes, &c., £25. each. Now there will be one of these required for every section of propulsion pipes, on each line of rails; and not, as in the case of the propulsion receivers, one, to feed two sections, that is, to work both lines of rails; therefore 38 × 25	950	0	0
Expense of establishing Hydraulic Propulsion, on a Railway, 2⅜ miles, in length, for both lines of Rails	£18,151	12	6

Hence the gross first cost for one mile of railway may be taken at	7642	0	0

But from this gross first-cost, deduct the value of the valves, and air vessels, and the difference between the value of the propulsion pipe, and continuous valve, and that of the skeleton pipe and wire rope, on so much of each line of railway, in every mile, as this alteration would apply to, from the inclines being favourable, and the trains, with the aid of the momentum in them, being able to descend without any decrease in speed.—(N.B. Over such portions of the rails, the skeleton piping and wire rope, only would be wanted.)—On Railways already established, this deduction would not often be very large in amount. On Railways, to be established for Hydraulic propulsion, it would be very considerable, as the distance to which it would apply, probably would frequently be equal to one third of the cost of the whole line.

Deduct for diminished weight of rails, in consequence of locomotive engines and tenders—which comprise an immense load within a contracted length of rail—being dispensed with, and the weight of the trains being spread evenly over a sufficient length of the line. This will probably effect a saving of, from £400. to £500. per mile, as in the atmospheric system.

Deduct, for diminished height of tunnels, in consequence of their present extra elevation to allow the chimney of the locomotives to pass, not being required: deduct also, for diminished height of bridges over the line, and adjoining earthworks.

jections; we will suppose it should be said, hydraulic propulsion could not succeed, for it could give no alarm; it had no whistle! Individuals of a mechanical turn of mind would immediately answer; surely this may be remedied; it cannot comprise any insuperable objection. The fact is, I intended to have explained a little arrangement for giving an alarm, earlier in the pamphlet, but it escaped my recollection, at the time. However it is this. Run a small elastic strap over a pulley on the axle of the hind pair of wheels, and bring it up through an opening in the bottom of the truck, into the driver's compartment; then pass it over a loose pulley, when not required to be in use, and move it on to an adjoining fast one, when its assistance is required. Now let this fast pulley, by the aid of a small crank, work a *small* pair of bellows communicating with three or four little, high-toned, shrill organ-pipes or whistles; to them, attach keys; and the driver or guard will then be enabled to convey as many alarm notes and intimations along the line as could possibly be required. I am rather surprised the guards, seated on the tops of the coaches, on the locomotive system, have not something of this sort to convey their communications, and orders to the drivers on the engines.

I mentioned in an early part of this treatise, that the circumstances of the case, seemed to require that, before concluding this pamphlet, I should bring hydraulic propulsion into a state of fair comparison with the atmospheric railway, as the two systems were, by many individuals supposed to be analogous in character;* and that whatever position one might stand in before the public, would be equally that, due to the other. I will dispose of this subject in a few words: the atmospheric system proposes to work under half an atmosphere; the hydraulic, under six atmospheres; the atmospheric proposes to lay a driving-pipe along the whole section of the line, of, from 15 to 18 inches in diameter; the hydraulic requires a pipe of 12 inches diameter over one-third of the whole line, aided by light additional skeleton and feed-pipes; the first has to incur the heavy expense of boring the pipe; the second has not; the first appears, from the power of the engine, which is to work the Dalky-extension of the Dublin and Kingstown Railways, to require fully four times the steam power of the second; but this should not be insisted upon,

* I must here again refer to note B.

[…]E B, PAGE 20.

[…] this note refers, I now insert below an
[…]d to me by the editor of a periodical of
[…]One or two remarks in it might appear to
[…]r publication) as they allude, rather in un-
[…]er invention for propulsion, now before the
[…]pheric railway. I have, however, submitted
[…]tion of some judicious friends, and they are
[…]cide with them, that the circumstances of
[…]rative upon me, in the course of this work, to
[…]the leading features of my invention, from
[…]that of the atmospheric system. This can
[…] a less unfavourabe construction, than might
[…]e months back; as the Dublin and Kingston
[…]resolved to extend their line about a mile and
[…]y) on the atmospheric principle. The ultimate
[…]h the atmospheric railway must shortly assume
[…]can no longer be affected by the remarks of any
[…]subject, whether favourable or otherwise: its cha-
[…]will be determined by the results of the trial, to
[…]now being practicably submitted by the Dublin
[…] Company. At the same time, any remarks I
[…]e way of bringing into fair contrast, the prin-
[…]my own, with those of this very ingenious and
[…]rtainly be as brief as the subject will admit of.

[…]th, 1842.—"Whatever plan you adopt, it
[…]drawing up your description, to assume that
[…]of the nature of your patent. It may even
[…]ing perfectly intelligible—and it is only by
[…]ect it to be appreciated as it deserves—to
[…]ostatics, which is not at once obvious, or
[…] This is the more necessary, as an opi-
[…]neumatic railway is a failure; and with
[…]f yours than the name, it is apt to b[…]
[…] I do not say this without reason.

a sound knowledge of the principles of the circumstances attending such motions leisure to enter into such inquiries, unless in a condensed form, with clear directions tion to practice.

"A work of this nature having been pu fessor Eytelwein, an abstract or summary by Dr. Thomas Young, with such modific he considered would add to its value to an mary was first published in the journals 1802, and the importance of so comprehen hydraulics, being immediately connected mental papers, was so evident, that we solici to republish it; and it was granted in manner."

There is an important chapter, and one of tract, with a very material extended note on formulæ in which I take my data, in this and proving the beneficial results to accrue propulsion as the driving agent on railways. "the motion of water in pipes," (chapter 13) and satisfactory, for all practical purposes—or think I shall be able to show, on the safe side that in Dr. Young's work of twenty-four chap devoted to that important subject; comprising leading principle, which governs the supply which, very probably, also contains within it, other important purposes, without considering how affect and confirm to the principle of railway hydr Young's tract, however, as intimated in the text, respect, particularly when the working out of this scale, is in question; indeed, if the work alluded to is in bestowing more attention to this subject, than some other writings. But I shall have to recur think I shall be able to establish, at least a strong formulæ or rule—on which on the present occasic *better data,* I am ready to base the claim of my *notice—will be deficient* in amount of result.

have again and again heard the assertion made; and you may depend upon it, that your patent would have had a fairer chance of being speedily adopted, had the pneumatic railway never been proposed."

Note C, page 24.

"Since falling bodies are in this manner accelerated (*i. e.* as the odd numbers) it may seem difficult, perhaps to conceive how a perpendicular pipe fixed at the bottom of a vessel of water, should continue, during the efflux, always full; which, strictly speaking, ought not to be so, on account of this acceleration, which ought to cause the water to run out of the pipe faster than it really could come in: whence it might be apprehended, that in time the pipe might be empty, before the water was all out of the vessel. To which we reply, that though *all bodies are by gravity accelerated in their fall, in the proportion of the odd numbers, already mentioned;* and must allow that if two heavy bodies A and B, be let fall one second after another, the first would get ahead of the other; nor would they keep at an equal distance during their descent. For, if at the end of one second after A is let go, B should be delivered, the first would be proceeding at the rate of 3, while the other is getting on but at the rate of 1. During the third second, A will be urged on with the force of 5, while B can have obtained the celerity but of 3. So that, if at the end of the first second, they were but a rod asunder, at the end of the second, they would be three rods apart, five at the end of the third, seven at the end of the fourth, and so forward, progressively. Yet it ought here to be considered, that the water in our perpendicular pipe, does not run into and out of it successively, and by starts, but evenly and continually. And though by the acceleration of falling bodies, their velocity does increase, on which account the water, in its progress through the pipe, if the resistance of the air, and every other impediment was away, might be allowed to be a small matter rarified; yet as the particles of water contained in the descending pillar set forward one after another in spaces of time infinitely short, and, being tenacious, adhere pretty well
appear, as to the sense, to make an even stream, and
It is, therefore, impossible that, so long as ther
for a supply, such pipe should become vo

tion any more than a nicety."—*The Motion of Fluids, by Mr. Clare, A.M. and F.R.S., second edition,* 1737.

The above extract may possibly, to parties who have not attended to hydrostatics, convey several ideas that will be new to them, the importance of which in the science, they will probably, now they are brought before their minds, be able, in some degree, to appreciate. Some of Clare's *reasons*, however, will, on a little reflection, probably appear not so indisputable as his facts.

Note D, page 26.

"The author (Young, on Eytelwein) has attempted to simplify this subject nearly in the same manner as that of the motion of rivers, and apparently with considerable success. He observes, that the head of water may be divided into two parts, one of which is employed in producing velocity, the other in overcoming friction: that the height employed in overcoming the friction must be as the length of the pipe directly, and also directly as the circumference of the section, or as the diameter of the pipe, and inversely as the content of the section, or as the square of the diameter; that is, on the whole inversely as the diameter; this height, too, must vary, like the friction, as the square of the velocity."

(Here follow algebraical formulæ, too long and complicated for any but a professed mathematician to work out, even if he would willingly encounter it practically; but at the foot of the paragraph is a valuable note by Tredgold, from which I extract as follows):—

"From this equation some exceedingly useful practical rules may be derived. In its present shape it only shows the velocity of water flowing through pipes; and is equivalent to the following rule:—

"To determine the velocity of discharge of a pipe, when the height of the water in the reservoir above the point of discharge, and the length and diameter of the pipe are given:

"Rule.—*Multiply* 2,500 *times the diameter of the pipe, in feet, by th- [illegible]ght in feet, and divide the product by the length in feet, added [illegible]s the diameter, then the square root of the quotient will be [illegible] of discharge in feet per second.*

" Example.—Let the
of the water in the reserv
the length of the pipe 146

$\frac{2500 \times}{14637 \times}$

very nearly, and the square
1·816 feet per second. Th
water pipes, described in
edition), and the actual velo
—*Tredgold's Tracts on Hyd*

This rule will be found
that is, the velocity due to wa
any length of vertical piping,
of any extent of horizontal pi
connected with any pillar of ve
rule must be accepted exactly
while, in the first, that part of t
the product by the length in t
must be understood as giving
only, there being in this case no

NOTE E,

This anticipated reduction in the reta
till it approaches the cube inversely, in
be satisfactorily accounted for. Let the
when unaided by any material momentum,
understood, inversely as the square. Th
powerful momentum comes into full play,
regard to accuracy, be left out of the acco
default of sufficient data, that it will possess
to the bulk when multiplied into that velocity,
quoted, assumes as being due to a column of
conditions: then, the advantage gained by the
due to increased bores, being multiplied into the al
will most probably furnish a result very near th
the square will be rejected, and the cube approxima

OBSERVATIONS

AND REFERENCES

TO THE

FIGURES IN THE DRAWINGS, &c.

OBSERVATIONS.—Hydraulic propulsion is intended to derive its power from the force of water under considerable pressure, in pipes. It is proposed to apply this pressure upon, or behind, a travelling piston in a pipe, and to carry the power so derived, by a flat iron plate, rising out of the crown of the piston, through a longitudinal continuous cleft in the pipe, and then to apply this power, when thus brought out of the pipe, upon a train upon a railway;—the continuous cleft to be filled up by the peculiar working adjustment of a continuous flexible valve, just as the piston passes; and so as to close and make the pipe water-tight, which is behind it, and filled with water. The hydrostatic force of water in pipes, under adequate pressure, is very great; and were there no retarding influence to its free passage up pipes, its application upon machinery would be remarkably simple. It happens, however, that, at high speeds particularly, the friction or retardation in the water increases, with the length of the pipe, very materially. Hence, it becomes necessary to keep each section of the "propulsion-pipe" of a moderate length, to adopt its final velocity as the driving speed, and to run the trains, by the momentum or impetus, which has [illegible] thrown into them, from this source of power in the propulsion-[illegible] a certain distance further over a section of "skeleton-pipe," [illegible] more power being expended on, or rather being made to follow [illegible] when they are full of driving force. This arrange-[illegible] render it necessary for the water, under pressure, being con-[illegible] during the intervals between the passing of the trains [illegible] additional pipe, to "propulsion-receivers" (or store-r[illegible] [illegible] power), to be placed in positions adjoining th[illegible] [illegible]-pipe (as they will occur at regular intervals [illegible]

the line,) from which the water may be again discharged, as the trains go by, into those sections of pipe. Thus, this system of propulsion is founded on those laws of hydrostatics, which give power over a limited extent, at a great velocity, and power over almost any extent, at a proportional slowness of speed: and it is from the mutual co-operation, or rather from the reciprocal action of these two laws, in the manner intimated, that railway hydraulic propulsion is enabled to promise that amount of beneficial result, which, in this pamphlet is claimed for it; the authorities for which, are brought forward, and the necessary calculations given.

Frontispiece.—It has been intimated to me, that, as the drawing shows nothing but the machinery of the system, it may, to some, convey the idea, that hydraulic propulsion appears to be replete with it. I have, therefore, thought it well to exhibit a portion of a railway, ninety-two yards in length, as it would appear to the eye, when a train was passing. This extent of line, I have obtained in the frontispiece, on a scale of ½ an inch to the yard, by showing it in two lengths, one below the other. This enables me to exhibit, first, a small portion of skeleton piping, then a " first power station," acting immediately from the pressure of a vertical column of water, brought down by piping, from high ground contiguous to the railway: after that, this arrangement enables me, at the commencement of a section of propulsion-pipe, to show the first motion of the machinery, or, at least, so much of it as can appear to the eye; the remainder of it, being equally diminutive, if thus brought into juxta-position with all the great objects about it; I can then exhibit a train of carriages, headed by the driving truck; and I am enabled to complete the seventy yards of propulsion piping, by showing, the reversing machinery and air vessel in their proper, relative positions: after which, this railway sketch terminates with a few yards of the next section of skeleton pipe. Now, to assist in conveying, from this little frontispiece, a just idea of the proportions of the system, it is proper to state that, though only one line of rails is here exhibited in working order; yet a large portion of the most important part of the system may be rendered common to both lines of rails, just as well as confining it to one only. Another ' also should never be lost sight of; namely, that the machinery , in the frontispiece, is shown as working 92 yards of railway, ' *be all that would be required for two hundred and twenty* · *the rest* of that distance being skeleton pipe, with no working *whatever upon it.*

REFERENCES TO FIGURES AND LETTERS, &c.

A A.—Skeleton pipe.

B B B.—Vertical column pipe, with its curves, to fall into propulsion-pipe.

C.—Junction of vertical column, and propnlsion-pipes.

D D D.—Propulsion piping, one inch in thickness.

E.—Water thrown into propulsion-pipe, behind the travelling piston, by the partial lifting of the communication valve.

F.—Communication valve.

G.—Interception valve, closed against its seat, being thrown up by the first rush of propulsion water, through the junction C. It will be held upon its seat till the pressure of the water is cut off.

H.—Air valve (Fig. 2) half-open, and only requisite when *t t* are required to act.

J.—Stop valve to arrest the progress of the water when the piston has passed forward, out of the propulsion-pipe.

K.—Discharge spout, which will frequently require to be placed at the other end of the propulsion-pipe, where it joins the skeleton; *i. e.* when the inclination of the piping is in that direction, and when the water must consequently be drawn off at that end, and close to the vertical column pipe.

L L.—Travelling piston, with its guide-neck before it.

M M M.—Pulley wheels to carry and direct the piston and guide-neck. The first pulley, near the snout of the guide-neck, is fixed vertically (there will be a second wheel on the same axis making a pair; the continuous valve, passing along the space, between this pair.) The second pulley wheel is fixed horizontally, and the third, behind the piston, vertically, thus in every direction guiding it clear of the sides of the pipe.

N.—Axle of the driving truck (Fig. 7.)

O O O.—Continuous flexible valve.

P P.—Wire rope to keep up the connection along skeleton piping, *with continuous* valve in driving (propulsion) piping.

j.—Continuous cleft in propulsion-pipe to receive continuous valve as travelling piston passes.

k.—Iron arch or passage through bottom of power-connection-plate, where it divides to admit continuous valve through (see in transverse section at Fig. 6.)

m m.—Rings of leather or Caoutchouc, nailed down to the piston, on one side of each ring, and forming its gills.

l.—Piston valve, used only to prevent accidents.

19.—Piston valve rod.

20.—Branched part of piston valve rod, to carry it round guide-neck, and so upwards.

21.—Upright rod, being a continuation of 19 and 20.

22.—Head of the above and bar on which it slides.

23.—Connecting rod to the above.

24.—Bell crank to convey action to the above.

25.—Screw with its lever handle, to work the above; that is, through the connecting rods, &c., to open the piston valve, and to close it again.

n n.—Incline or driving truck to throw up pulleys 12 and 18, as the truck passes.

p p p.—Bent, double forked lever, with its long axis, to slot the incline back close to the truck, when the driver wishes to stop the train. This it will cause, by its being thus placed out of reach of the pulley, when the communication valve to throw water into the propulsion-pipe will not be acted upon.

r r.—Rod and handles, to work the above.

s s s s.—Wheels of driving truck.

u u.—Strong springs carrying power connection-plate, and allowing a little play, in case of any unevenness in the rails.

t t.—Two pulleys or friction wheels to put continuous valve down, in case it ever sticks in continuous cleft, so as to enable it to enter *k* freely.

w w.—Supports from driving truck for above pulleys.

26.—Traddle to close stop-valve, acted upon by front pair of pulley wheels M of travelling piston L.

27.—Bell crank, carrying the action of the traddle forward, by the aid of the small connecting rod between them.

28.—Longer connecting rod between the two bell-cranks.

29.—Second bell-crank to apply action of traddle upon stop valve.

30.—Supports from the skeleton pipe, to the two bell-cranks.

31.—Stop valve rod.

32.—Stuffing box.

33.—Stop valve box.

34.—Additional lever to ensure the due opening of the stop valve, if it should ever not fall by its own gravity, as soon as water, which holds it, by strong side pressure, upon its seat, is withdrawn.

35.—A support to the above from the propulsion-pipe.

36.—Two prongs to end of lever, which, when not to act, play freely between 31, but in case stop valve ever sticks, press upon boss at 37, and throw it down.

37.—Above-named boss.

38.—Stirrup to 34 playing loosely on boss at the end of 16, except when an obstruction at the other end of the lever (i. e. the sticking of the stop-valve) causes boss to press firmly upon the upper end of this stirrup, and so produce action on stop valve.

x x.—Air-valve box.

y.—Lever with load to assist the leverage to the communication valve in reversing action. It also retains the communication rod at a proper tension.

z.—The above load.

39.—Orifice from propulsion-pipe into connecting pipe, to air vessel.

40.—Above connecting pipe.

41.—Clack valve, opening inwards, in the air vessel, to prevent the recoil of the water into propulsion-pipes.

42.—Air globe (self-acting) to lift small discharge valve, 43, when sufficient water has passed into the air vessel to float the globe. The water, so discharged, is to be carried off in a proper drain, for use again, or to run to waste, as occasion may dictate.

43.—Discharge valve above mentioned.

44.—Manhole. This number also refers to the manhole in the propulsion receiver.

45.—Junction of receivers feed-pipe U, and of curved branch W, with vertical column pipe.

46.—Chairs.

47.—One line of rails.

48.—Sleepers.

49.—Blocks.

50.—Holdfasts to bolt down to blocks or chairs.

Fig. 3.—(Drawn to half scale.)

51.—Connecting pipe to propulsion-pipes, of the same character as the curve at B. The other piping in this figure is explained by the letters on it (being the same as on the other figures), and shown without valves, &c., which leaves the propulsion-pipe, its arrangement, open to view.

52.—Air globe on its lever or guide-arm; to be of sufficient load to throw open valve 55, against a preponderating pressure.

53.—Upright rod, down to valve at 55.

54.—Stirrup, through which guide-arm of 52 moves, so as to establish action of valve only just before the full charge of propulsion water is thrown from the receiver into the driving pipes, and so as to close the valve again quickly, just as the receiver is replenished with another charge.

55,—Feed valve between receiver and its feed-pipe U, opening downwards.

56.—Connecting rod from 55 to 57.

57.—Small interception valve and box, to close when 55 is open, and to open when it is closed; thus turning the water into this receiver or allowing it to pass on to the next, as required.

58.—(Figs. 1 & 7.) Partitions in driving truck, inside, to box off so much of the wheels as would be otherwise there exposed.

59.—Guard's box, in that division of the truck which is divided off for him and the driver.

60.—Seats for the guard and driver.

Fig. 8.—*(Drawn without any proportions,* as already explained.)

61.—Vertical column pipe.

62.—Propulsion receivers.

63.—Ditto piping, on one line of rails, to represent 70 yards on each curved line.

64.—Skeleton piping, to represent 150 yards in each small dotted section shown of it.

65.—Propulsion piping, representing (as at 63,) a section of 70 yards, in each branch, to reverse direction of driving power (as indicated at W in preceding figures) for the other line of rails; say, for that, not exhibited in this drawing.

66.—The two lines of rails.

67.—Propulsion receiver's feed pipe.

Manchester: Printed at SIMPSON and GILLETT's Steam Press.